Middle Atlantic Bight Field Study: SUS Component

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LONG-TERM GOAL

Our long term objective is to investigate the feasibility of using broadband explosive sources such as SUS charges for inversion of oceanographic fields and sediment parameters. We have performed non-linear inversions using a combination of global search methods (Genetic Algorithm) and local least squares optimization schemes (Levenberg - Marquardt). The inverted oceanographic fields are coefficients of empirical orthogonal functions of the sound speed field in the water column, sediment compressional wave speeds at various depths, bathymetry and source-receiver range. The ocean sound speeds and bathymetry are assumed range dependent while sediment is assumed range independent. We are also estimating the spatial resolution and error properties of the inverted fields and parameters.

OBJECTIVES

The S&T objectives of this work deal with the effects of a complicated shelfbreak front and sloping bathymetry on acoustic propagation. Low frequency acoustic propagation in areas with varying bathymetry is affected by the presence of oceanographic features like frontal zones, internal waves and solitons. The effect of these features on the acoustic propagation in this severely range dependant environment is studied in the Primer Field Study. The analysis of the data collected using the tomographic sources are being carried out at WHOI, NPS and MIT. At URI we are analyzing the broadband data collected during the SUS operations with specfic emphasis on geoacoustic inversions.

BACKGROUND

This research project is part of the integrated acoustic-oceanographic Shelf Break Primer field study in the Middle Atlantic Bight. This work is complimentary to the work being conducted at the Woods Hole Oceanographic Institution, Naval Postgraduate School, and Harvard University. The overall goal of the field study is to understand the propagation of sound from the continental slope to the continental shelf including the effects of shelf-break frontal features and seasonal stratification. In this project, we have used the broadband low frequency SUS signals to invert for sediment parameters. URI tasks relate particularly to the design and execution of the SUS experiment, data processing and analysis and inversion for the geoacoustical parameters.

APPROACH

Hydrophone array time series of the shot data was analysed using wavelet based methods to obtain time-frequency dispersion curves for the mode arrival patterns (figure 2). The group velocity values

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were peak picked as a function of mode number and frequency for modes 1-9 and for frequencies 20-200 Hz. Interesting features in the wavelet scalogram include a very low frequency precursors to the water borne arrival, 5 seconds of significant reverberation and evidence of modal dispersion.

 Now we have completed the inversion of a signal from a SUS charge deployed at approximately 98m of water depth assuming adiabatic propagation. Nonlinear optimization was perfomed using the combination of a global scheme (Genetic Algorithm) and a local least squares method (Levenberg-Marquardt). In addition to the sediment compressional sound speeds at various depths, sound speed variations in the water column (using Empirical Orthogonal Functions), water depths and source-receiver range were treated as unknown parameters. A sensitivity study was carried out to quantify the effect of these parameters on group speed values. The propagation path was divided into five segments. The sediment parameters were assumed range independent while sound speed in the water column and bathymetry were assumed range independent.

RESULTS

In the first phase of this study signal from one of the SUS charges, deployed near the North West corner of the experimental area, received at the North East VLA was analyzed assuming range independent propagation and used for inverting the sound speeds in the water column and the sediment. We were able to compare these values with the compressional speeds calculated using Biot-Stoll model at a nearby Atlantic Margin Coring Project site (AMCOR - 6012). These results were presented at the meeting of the Acoustical Society of America at San Diego during 01-05 December 1997. Now we have completed the analysis of another SUS signal further down the slope assuming mildly range dependent conditions and these results were presented at the meeting of the Acoustical Society of America at Norfolk during 12-16 October 1998. The compressional sound speeds obtained by this inversion is shown in figure 3. The standard deviations are of the order of 30 m/s. Figure 4 shows the comparison of experimental data with inversion.

IMPACT/APPLICATION

This experiment and subsequent data analysis will have direct and immediate impact on Navy system design, operations and tactics. The ASW problem posed by quiet diesel submarines inshore of Navy assets on the continental shelf poses difficulties for deep water Low Frequency Active Acoustic systems and air-deployed explosive ASW systems. The results from this work will allow system designers to assess system capability in regions of the world with upslope and 3-D propagation, continental shelf and slope, and fronts. Operators will be able to improve system performance by using the optimum frequency analysis from this work. The use of Navy air ASW systems will be affected by the results of this study. In addition, the work may provide a technique for fast and inexpensive estimation of sediment properties in littoral waters to 10's of meters below the sea bottom. We think that once the technique is perfected, only a VLAD sonobuoy and a number of SUS charges could provide range dependent sediment maps with range resolution of a few kilometers and depth resolution of meters.

RELATED PROJECTS

This project is directly related to a number of classified Navy projects in SPAWAR, NAVAIR, NRL, and the Submarine Security Office. All of these projects are directed toward the detection,

classification, and localization of submarines in a littoral environment. Further information on these projects can be obtained directly from the P.I.
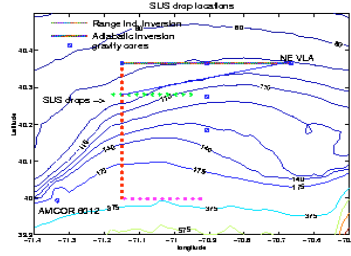

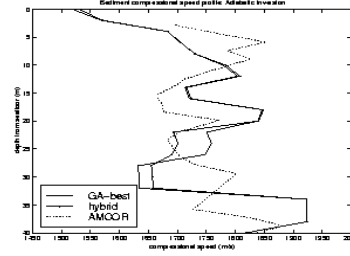Figure 1: Locations of SUS drops and AMCOR drill site.

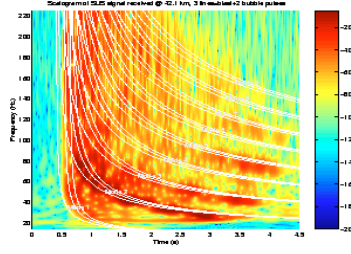Figure 3: Sediment compressional speed inversions.
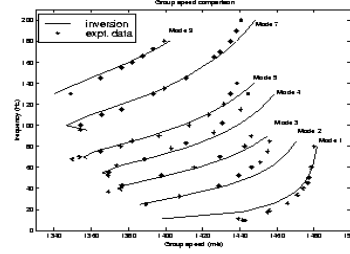

Figure 2: Wavelet scalogram of SUS signal.

Figure 4: Group speed dispersion- experiment and theory.

Comparison of inversion results with AMCOR data and Group velocity dispersion. Figure 1 shows the SUS drop locations marked by asterisks and the Northeast Vertical Line Array by a circle. The horizontal solid line is propagation path for range independent inversions and diagonal line for the adiabatic inversions. Figure 2 shows the wavelet scalogram of the SUS signal. Figure 3 shows the inversion results and the Atlantic Margin Coring (AMCOR) sound speeds. Figure 4 shows the agreement between the measured and the modeled dispersion for modes 1-4 in the frequency range from 20-200 Hz.